CLAIMS

1. An iron-based rare-earth nanocomposite magnet having a composition represented by the formula: $T_{100-x-y-z-n}Q_xR_yTi_zM_n$, where T is either Fe alone or a transition metal element in which Fe is partially replaced by at least one element selected from the group consisting of Co and Ni; Q is at least one element selected from the group consisting of B and C; R is at least one rare-earth element including substantially no La or Ce; and M is at least one metal element selected from the group consisting of Al, Si, V, Cr, Mn, Cu, Zn, Ga, Zr, Nb, Mo, Ag, Hf, Ta, W, Pt, Au and Pb, the mole fractions x, y, z and n satisfying the inequalities of

$5\ \text{at\%} \leqq x \leqq 10\ \text{at\%}$,

$7\ \text{at\%} \leqq y \leqq 10\ \text{at\%}$,

$0.1\ \text{at\%} \leqq z \leqq 5\ \text{at\%}$ and

$0\ \text{at\%} \leqq n \leqq 10\ \text{at\%}$, respectively,

wherein the magnet includes $R_2Fe_{14}B$-type compound phases and α-Fe phases that form a magnetically coupled nanocomposite

magnet structure, and

wherein the $R_2Fe_{14}B$-type compound phases have an average crystal grain size of 20 nm or more and the α -Fe phases are present in a grain boundary region between the $R_2Fe_{14}B$-type compound phases and have a thickness of 20 nm or less, and

wherein the magnet has magnetic properties including a coercivity of at least 400 kA/m and a remanence of at least 0.9 T.

2. The iron-based rare-earth nanocomposite magnet of claim 1, wherein the $R_2Fe_{14}B$-type compound phases have an average crystal grain size of 30 nm to 300 nm and the α -Fe phases have an average crystal grain size of 1 nm to 20 nm.

3. The iron-based rare-earth nanocomposite magnet of claim 1, wherein the ratio of the average crystal grain size of the $R_2Fe_{14}B$-type compound phases to that of the α -Fe phases is 2.0 or more.

4. The iron-based rare-earth nanocomposite magnet of claim 1, wherein the α -Fe phases are present at grain boundary triple points of the $R_2Fe_{14}B$-type compound phases.

5. The iron-based rare-earth nanocomposite magnet of claim 1, wherein the α -Fe phases account for at least 5 vol% of the overall magnet.

6. A rapidly solidified alloy to make an iron-based rare-earth nanocomposite magnet, the alloy having a composition represented by the formula: $T_{100-x-y-z-n}Q_xR_yTi_zM_n$, where T is either Fe alone or a transition metal element in which Fe is partially replaced by at least one element selected from the group consisting of Co and Ni; Q is at least one element selected from the group consisting of B and C; R is at least one rare-earth element including substantially no La or Ce; and M is at least one metal element selected from the group consisting of Al, Si, V, Cr, Mn, Cu, Zn, Ga, Zr, Nb, Mo, Ag, Hf, Ta, W, Pt, Au and

Pb, the mole fractions x, y, z and n satisfying the inequalities of

$5\ at\% \leqq x \leqq 10\ at\%$,

$7\ at\% \leqq y \leqq 10\ at\%$,

$0.1\ at\% \leqq z \leqq 5\ at\%$ and

$0\ at\% \leqq n \leqq 10\ at\%$, respectively,

wherein the alloy has an average thickness of 50 μm to 300 μm, and

wherein the alloy includes at least 20 vol% of $R_2Fe_{14}B$-type compound phases with an average crystal grain size of 80 nm or less.

7. The rapidly solidified alloy of claim 6, wherein the alloy has a thickness with a standard deviation σ of 5 μm or less.

8. The rapidly solidified alloy of claim 7, wherein the alloy includes a crystallized layer at least on a free cooling

side thereof.

9. A bonded magnet including a powder of the iron-based rare-earth nanocomposite magnet of claim 1.

10. A method for producing an iron-based rare-earth nanocomposite magnet, the method comprising the steps of:

preparing a molten alloy having a composition represented by the formula: $T_{100-x-y-z-n}Q_xR_yTi_zM_n$, where T is either Fe alone or a transition metal element in which Fe is partially replaced by at least one element selected from the group consisting of Co and Ni; Q is at least one element selected from the group consisting of B and C; R is at least one rare-earth element including substantially no La or Ce; and M is at least one metal element selected from the group consisting of Al, Si, V, Cr, Mn, Cu, Zn, Ga, Zr, Nb, Mo, Ag, Hf, Ta, W, Pt, Au and Pb, the mole fractions x, y, z and n satisfying the inequalities of

$5\ at\% \leqq x \leqq 10\ at\%$,

7 at% $\leqq$ y $\leqq$ 10 at%,

0.1 at% $\leqq$ z $\leqq$ 5 at% and

0 at% $\leqq$ n $\leqq$ 10 at%, respectively;

rapidly cooling and solidifying the molten alloy to make a rapidly solidified alloy including at least 20 vol% of $R_2Fe_{14}B$-type compound phases with an average crystal grain size of 80 nm or less; and

heating the rapidly solidified alloy, thereby making an iron-based rare-earth nanocomposite magnet including the $R_2Fe_{14}B$-type compound phases and α-Fe phases that form a magnetically coupled nanocomposite magnet structure, where the $R_2Fe_{14}B$-type compound phases have an average crystal grain size of 20 nm or more, the α-Fe phases are present in a grain boundary region between the $R_2Fe_{14}B$-type compound phases and have a thickness of 20 nm or less, and the magnet has magnetic properties including a coercivity of at least 400 kA/m and a remanence of at least 0.9 T.

11. The method of claim 10, wherein the $R_2Fe_{14}B$-type compound phases have an average crystal grain size of 30 nm to 300 nm and the α-Fe phases have an average crystal grain size of 1 nm to 20 nm.

12. The method of claim 10, wherein the step of rapidly cooling includes quenching and solidifying the molten alloy to make a rapidly solidified alloy with an average thickness of 50 μm to 300 μm and with a thickness standard deviation σ of 5 μm or less.

13. A method of making an iron-based rare-earth nanocomposite magnet powder, the method comprising the steps of:

preparing the rapidly solidified alloy of one of claims 6 to 8 to make an iron-based rare-earth nanocomposite magnet; and

pulverizing the rapidly solidified alloy into a magnet powder.

14. The method of claim 13, further comprising the step of heating the rapidly solidified alloy that has not been pulverized yet or that has already been pulverized, thereby making a magnet powder including $R_2Fe_{14}B$-type compound phases with an average crystal grain size of 30 nm to 300 nm and α-Fe phases with an average crystal grain size of 1 nm to 20 nm and exhibiting magnetic properties including a coercivity of 400 kA/m or more and a remanence of 0.9 T or more.